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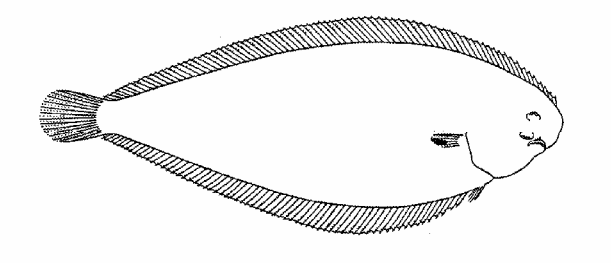
ICES-FishMap

Sole	*Solea solea* Family Soleidae	Max size: 70 cm Max age: 40 years



Introduction

Taxonomy: Sole *Solea solea* (Linnaeus, 1758) (Order: Pleuronectiformes; Family: Soleidae) is one of four members of the family that occurs in the North Sea. Erroneously, the synonym *Solea vulgaris* is sometimes being used in the literature. One congener, the sand sole *S. lascaris*, which is easily identified by the rosette-like expansion of the ventral nostril, is occasionally caught near the entrance to the Channel.

common names			
Danish	Tunge	*Icelandic*	Sólflúra
Dutch	Tong	*Latvian*	Jūrasmēle
English	Sole	*Norwegian*	Tunge
Estonian	Merikeel	*Polish*	Sola
Faeroese	Leistur	*Portuguese*	Linguado
Finnish	Kielikampela / Meriantura	*Russian*	Морской язык
French	Sole commune	*Spanish*	Lenguado común
German	Seezunge	*Swedish*	Äkta tunga

General: Sole is excellent consumption fish and of commercial importance. It is a southern species that reaches its northern limit in the North Sea. It lives buried in sandy or muddy bottoms, requiring heavy gear to be chased out and caught in trawls. Juveniles spend their first year in shallow coastal waters, the Wadden Sea and in estuaries. When they grow older they gradually disperse into deeper water.

Minimum Landing Size: 24 cm total length.

Distribution

Biogeographical distribution: The biogeographical range of sole extends from the northwest African coast and Mediterranean in the south to the Irish Sea, southern North Sea, Skagerrak and Kattegat in the north. They are sometimes caught in low numbers around Scotland and occasionally even along the southern coast of Norway [1,2].

As for plaice older and bigger individuals tend to occur in deeper waters than the juveniles, but they remain largely restricted to waters <50 m deep.

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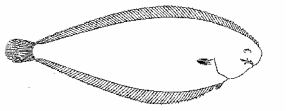
	Sole	***Solea solea*** Family Soleidae	

Spatial distribution in North Sea: Sole is mainly found in the southern and eastern North Sea, south of the line from Flamborough to North Jutland (Fig. 1). This line corresponds to the position of a steep temperature gradient that, in summer and autumn, divides the North Sea into a cold stratified northern section with bottom temperatures of about 7ºC and a warm mixed southern section with bottom temperatures of up to 17ºC [3,4]. Sole is also found in Skagerrak/Kattegat. Incidental catches are made off the Scottish east coast.

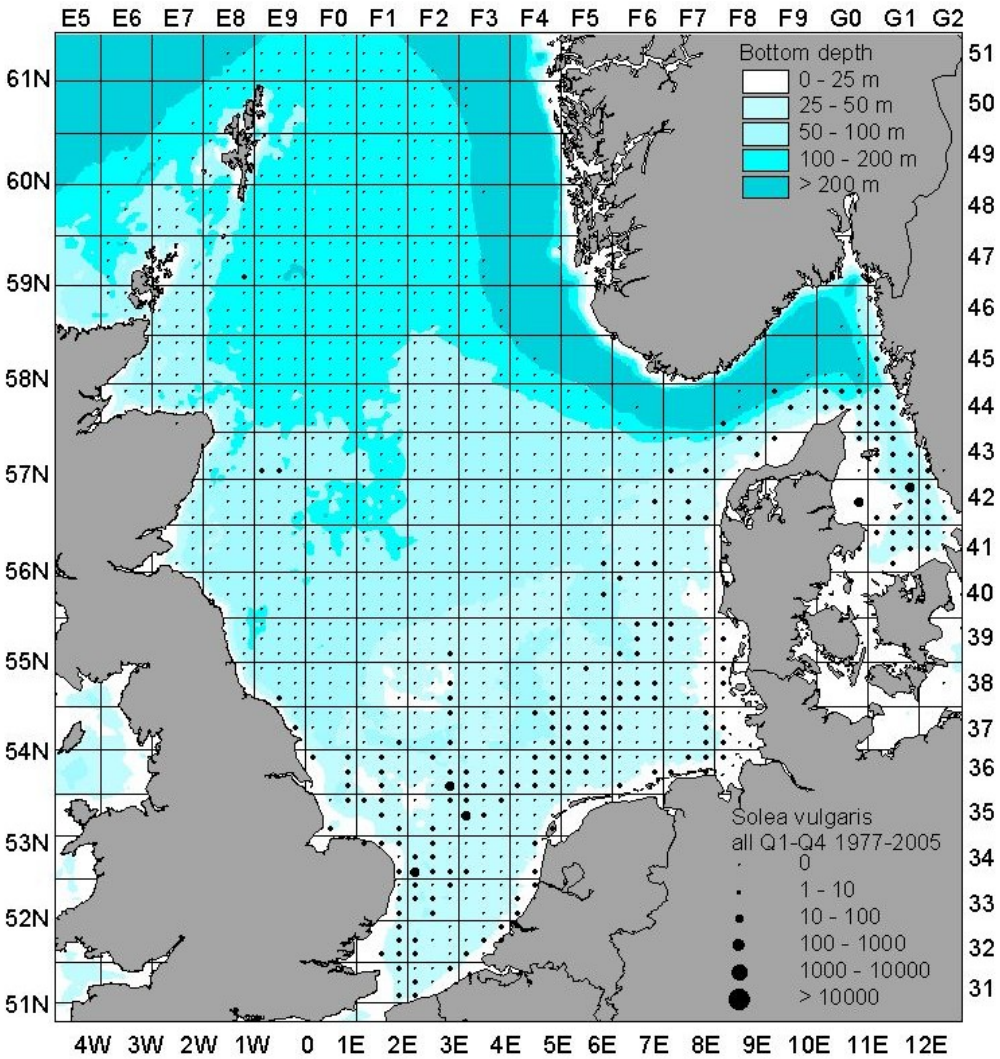
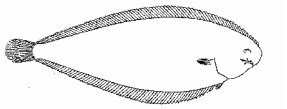


Figure 1. Distribution of *S. solea* during the quarter 1 IBTS survey, 1977–2005.

Sole

Solea solea
Family Soleidae



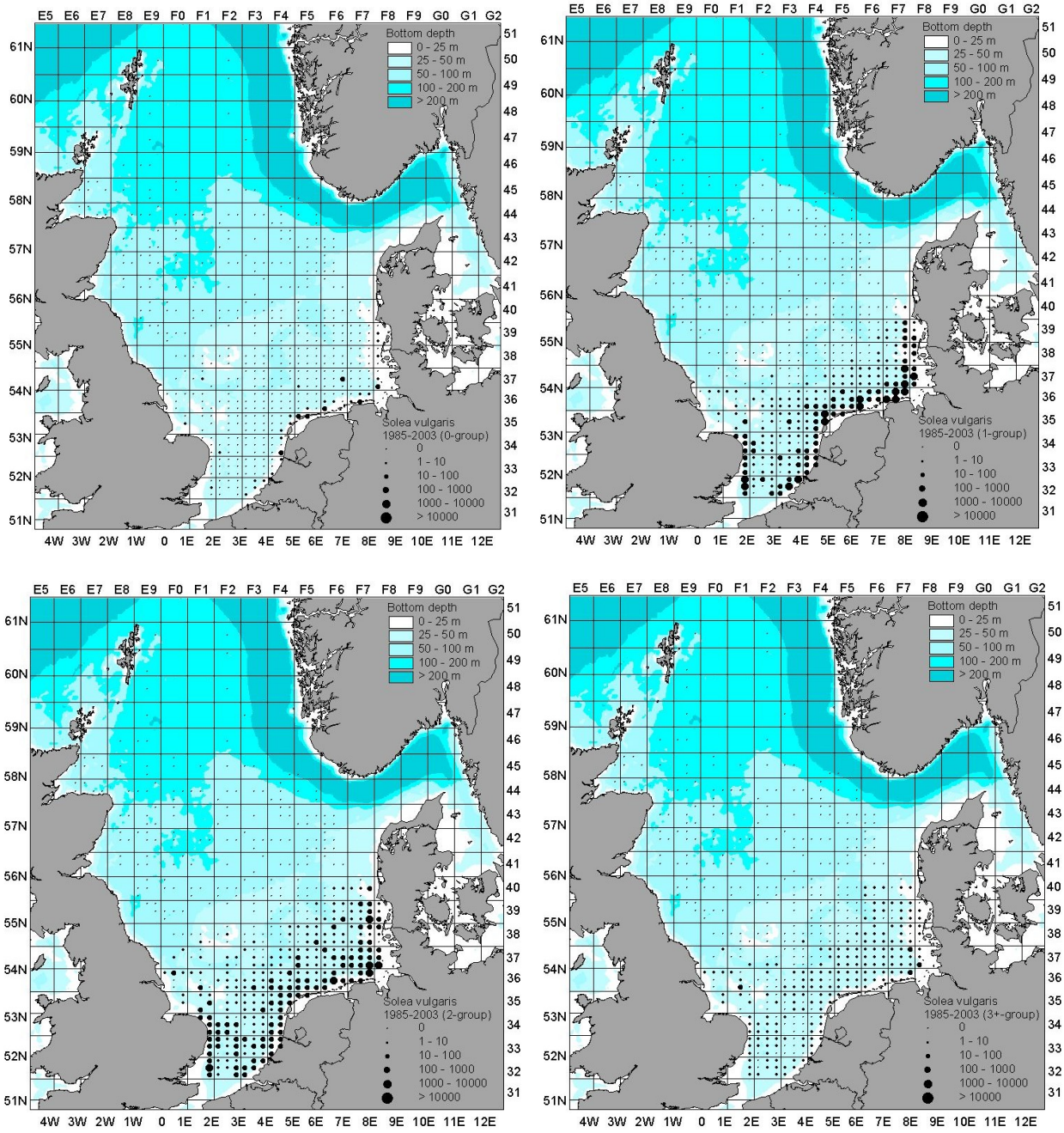
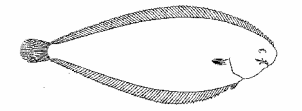


Figure 2. Average annual catch (number per fishing hour) for *S. solea* by age group in the quarter 3 BTS survey, 1985–2003.

Figure 2 illustrates that 0-group sole are restricted to very shallow coastal waters of the open North Sea, but 0-group are also found in the Wadden Sea and other estuaries outside the reach of the IBTS or BTS. The 1- and 2-group occur over slightly deeper waters, with older (3+) sole more evenly dispersed. The survey catches are dominated by 1 and 2-year-old fish.

	Sole	*Solea solea* Family Soleidae	

Habitat characteristics: Sole tend to occupy shallow, sandy and sandy/muddy habitats. Althoug such habitats are widespread in the North Sea and spawning occurs all along the southern coasts, five main spawning grounds can be distinguished: the inner German Bight, off the Belgian coast, in the eastern Channel, in the Thames estuary and on the Norfolk Banks (Fig. 3) [5,6]. Tagging experiments support the suggestion that the spawners return to the same spawning grounds year after year, but it is not known whether recruits return to the grounds where they were born.

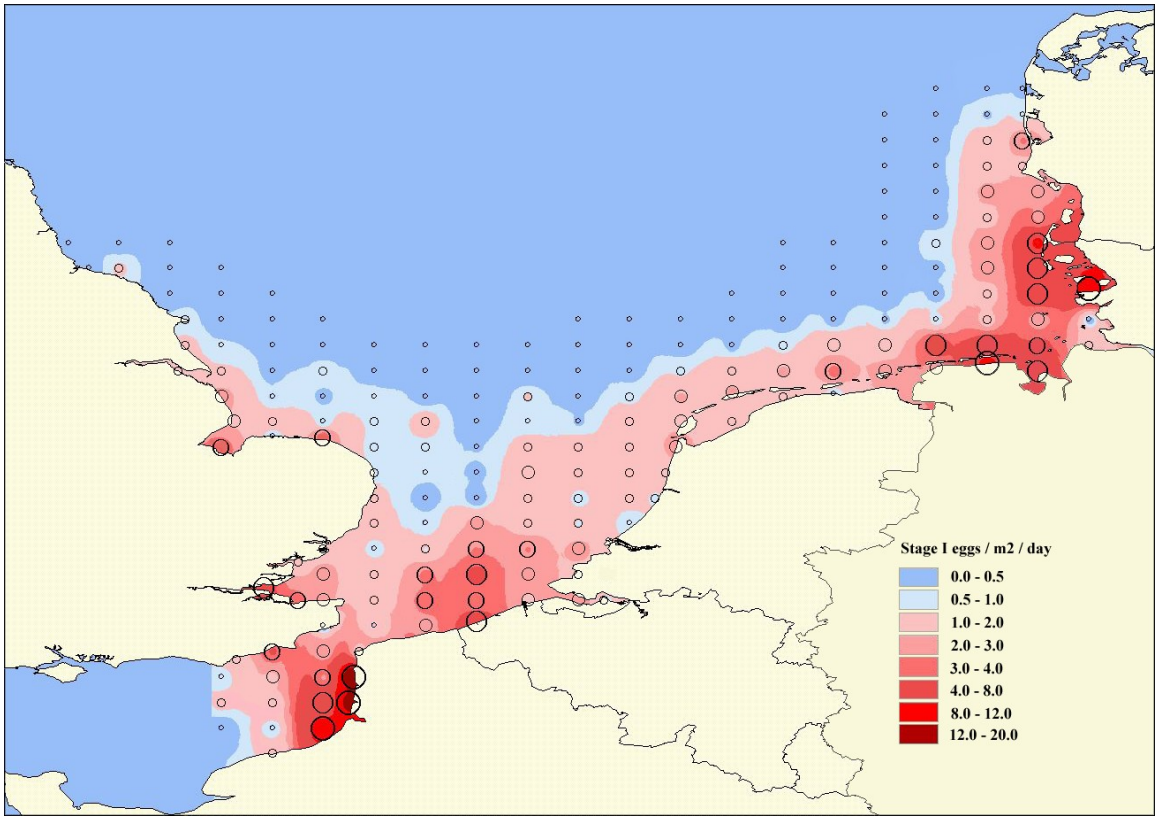


Figure 3. Spawning areas of *S. solea* in the southern North Sea based on the occurrence of eggs that just have been spawned (stage-1) [7].

Nurseries are situated all along the continental and English coasts in waters less than a few metres depth and on sandy or muddy bottoms, but the relative contribution of the different regions to the recruitment to the total stock varies considerably from year to year [8].

Life history

Age, growth rates: Length rarely exceeds 60 cm [9], but specimens up to 70 cm have been reported. The oldest specimen observed in Dutch landings was 40 years old. Females attain a larger size than males (Fig. 4) and big soles are invariably females.

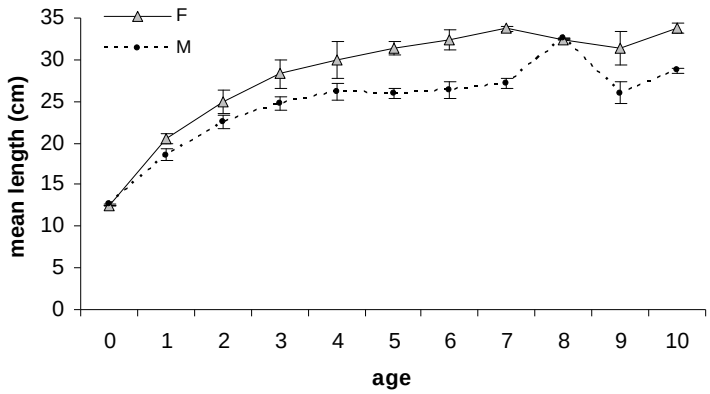


Figure 4. Length-at-age in sole. Data from the quarter 3 Dutch Beam Trawl Survey averaged over the years 2000–2003.

Growth rates have not been stable over time, and a marked increase in size at age has been observed during the 1960s for all age groups (e.g. 4-year-old specimens measured only 28.5 cm in the second quarter of 1957, compared to 32 cm in 1971) [10]. After reaching a peak in the early 1970s, growth rate has decreased steadily [11]. A possible explanation for these changes, which affected both sole and plaice, may lie in the initially increasing and subsequently declining input of nutrients from river runoff in the southeastern North Sea and the effects of eutrophication on food availability [11].

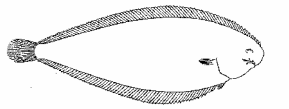
Reproduction: Spawning takes place in spring in coastal waters within the 30 m depth contour and is triggered by sea water temperature [3], the peak (usually in late May) being advanced during a warm spring [12].

Females produce between 700 and 800 eggs per gram body weight, which corresponds to about 350,000 eggs for a 35 cm fish [5,13]. The pelagic eggs are 1.0–1.6 mm in diameter.

Ambient temperature during the egg phase is about 10ºC, and between 10 and 15ºC during the larval phase [14]. At these temperatures, the pelagic larvae hatch after about 7 to 8 days at a size of 2.5 to 4 mm [15,16] and after metamorphosis the post-larvae settle on the bottom at a length of 7–10 mm, about 3 weeks after hatching [16]. Hence, the duration of the planktonic phase is very short, and settlement is usually close to the spawning area [5].

The proportion of mature fish at age has varied considerably over time, but without a clear temporal trend [17].

Recruitment: Because eggs and larvae are passively transported by currents over short distances only, the local abundance of 0-group is supposed to mirror the local spawning success [8].



Year-class strength appears to be determined somewhere during the pelagic egg and larval or early demersal juvenile phases, with recruitment patterns varying between different spawning areas [5].

Migrations: The mechanism by which the metamorphosing larvae reach their nursery areas is not well established. It is speculated that they are transported passively but using bottom currents selectively [18].

In autumn when temperatures fall, sole leave the shallow coastal areas and migrate to the warmer offshore grounds. Particularly in severe winters, they may form dense aggregations in the deeper and less cold parts in the southern North Sea and the eastern Channel [5]. For instance, the Silver Pit (rectangles 35F0 and 36F0) owes its name to the valuable catches of sole made there during cold winters. In March – May they return to inshore waters [19]. During these spawning migrations, which generally take place at night, the fish may even be seen swimming at the surface [20] and appears to make use of selective tidal transport [21].

Food habits: Sole is a nocturnal and olfactorial feeder, spending the day buried in bottoms with fine sediments [21,22]. The blind side of sole has many sensory organs to facilitate prey detection. Its diurnal behaviour makes them easier to catch during night time (because the surveys are almost exclusively carried out during daytime, catch rates underestimate absolute abundance).

The pelagic larvae feed on copepod nauplii [6]. Juveniles and adults in Dutch coastal waters feed mainly on polychaete worms, particularly *Arenicola marina*, *Lanice* spp. and *Nereis* spp., but small echinoderms (e.g. brittlestars and the small sea urchin *Echinocyamus pusillus*) may represent important prey for adults in specific areas [23]. In a French bay, juveniles feed on amphipods, young opisthobranchs, and again polychaetes, while siphons of various bivalve molluscs are eaten as well [22].

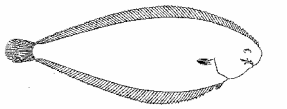
Sole and cold weather

During severe winters large catches of dead sole have been reported, indicating a direct mortality caused by extremely low temperatures. When temperatures fall below the critical temperature of 3ºC for prolonged periods, such as in 1963, mass mortality may cause a severe decline of the spawning stock [24,25]. However, after the cold winter of 1963 – as in 1947 after another severe winter – one of the strongest year classes ever was born, possibly because predators of larvae and juveniles had also suffered severe losses [5].

Population structure

Age and length composition: In the 1960s, extremely strong year classes could dominate the landings for many years and it was not uncommon to find soles that were over 20 years old. In recent years, soles over 10 years old are scarce and landings are dominated by 2 to 4-year-olds owing to heavy exploitation.

The length distribution in the surveys is dominated by one-year-old juveniles of around 10 cm, while a second peak is observed between 20 and 25 cm (Fig. 5). In the Skagerrak/Kattegat the catch is dominated by 2-years-old fish with a peak at around 22 cm. However, this difference will be affected by the data sources used to derive these length frequency distributions (BTS for the North Sea vs. IBTS for the Skagerrak/Kattegat area) In general, the GOV-trawl is less efficient in catching soles than beam trawls.

	Sole	*Solea solea* Family Soleidae	

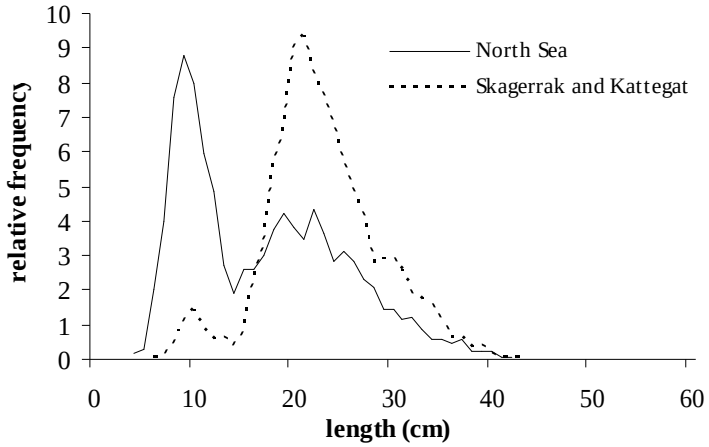


Figure 5: Length frequency distribution of sole. For the North Sea data from the Dutch Beam Trawl Survey (averaged over the years 1985–2004) were used. For Skagerrak/Kattegat IBTS data for the same years have been used.

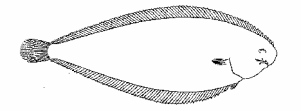
Changes in abundance: The temporal recruitment pattern is characterized by incidental very strong (1924, 1929, 1947, 1958, 1963, 1987, 1991) and very weak year-classes (1961, 1962 and 1978) [5,25]. Some of the very strong year classes are hatched after a severe winter. These strong year classes cause large fluctuations in stock size, especially under the recent regime of heavy exploitation.

Stock structure: Within the North Sea several different sub-populations have been distinguished based on egg distribution and tagging experiments. However, these are to a large extent mixed during the feeding season. Assessments examine the North Sea sole as one unit stock, with the stocks in the eastern Channel and the Skagerrak/Kattegat being assessed separately.

Exploitation in the North Sea

Main metiers targeting the stock: Up to the 1960s, sole was exploited mainly by otter trawls, but catchability was low and this safeguarded the stock. In the 1950s, heavy chains were introduced in this fishery to chase the sole out of the sand, but the higher catchability was offset by a reduced width of the net. In the 1960s, the beam trawl was introduced, which had the advantage that the width of the net remained fixed and a greater number of chains could be used. This beam trawl fishery expanded rapidly and in a run for the fish ever more powerful vessels were introduced to be able to use larger beams, more chains and to increase speed. Approximately 90% of the sole landings is now taken by twin beam trawlers in a mixed fishery for sole and plaice and other flatfish, while gill nets targeting sole are used locally in inshore waters, particularly during the spawning season. Since the mid-1990s the fishing effort of the major fleets exploiting North Sea sole has decreased somewhat [26].

Landings: After fluctuating around a few thousand tonnes before World War II, North Sea landings increased rapidly until the extremely strong 1963 year class, responsible for the big stock in 1966, lost its importance. Since then, landings have fluctuated between 15 000 t and 30 000 t. In recent years fish of the strong year classes 1996 and 2001 have dominated the landings [26].



Spawning Stock Biomass and fishing mortality: Stock size has fluctuated widely owing to the appearance of occasional strong year classes, but also by the mass mortality during the severe winter of 1963 [17]. However, periods of revival are short-lived as a consequence of heavy exploitation and overall there has been a downward trend. Since the late 1960s fishing mortality has been above the precautionary level of 32%. A limit level of F has not been defined for this stock [26].

Stock status: The stock is at risk of reduced reproductive capacity. The size of the spawning stock is above the limit level of 25 000 t, but fishing mortality is too high. The stock is therefore at risk of being harvested unsustainably [26].

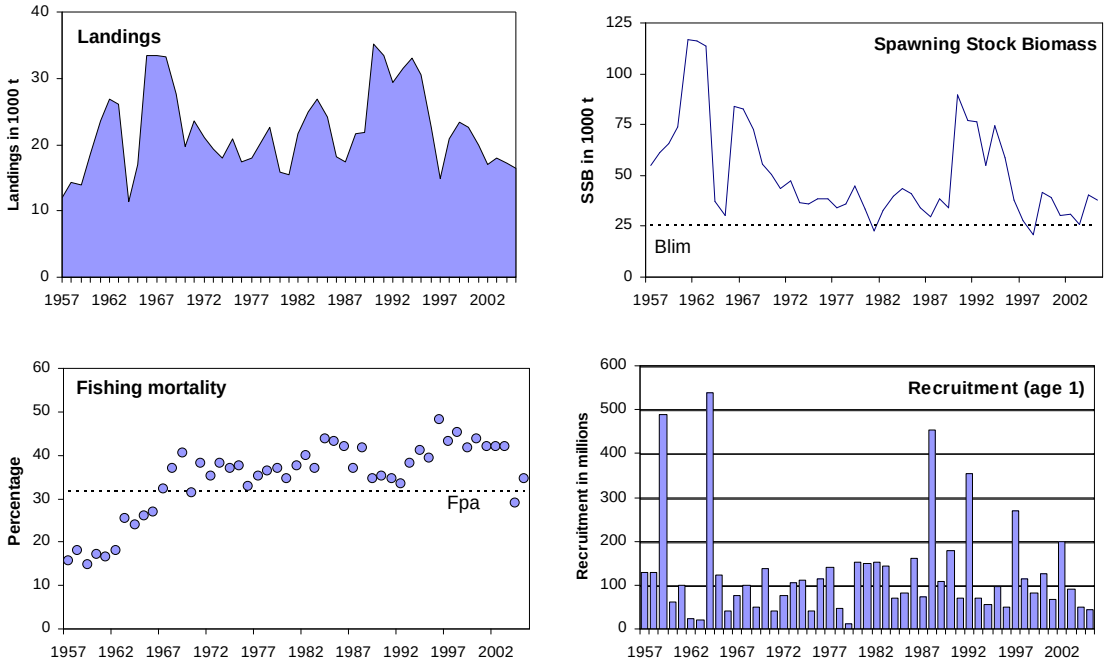
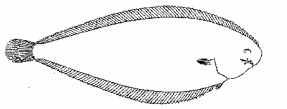


Figure 5. Landings and discards (‘000 t), spawning stock biomass (‘000 t), recruitment at age 1 (in millions) and average fishing mortality (in %) for ages 2 to 6 for North Sea sole since 1957 [26].

Protection and management: There are no explicit management objectives for this stock apart from applying the precautionary approach. The TACs are agreed between the European Commission and Norway and aimed to restrict the fishery [26]. However, because the species is caught in a mixed fishery and exceeding the TAC for one species may not prevent the fleet from continuing fishing, the effectiveness of TAC management is doubtful, to say the least.

Several technical measures, constrain the sole fishery, including mesh size regulations, gear restrictions and a closed area (Plaice Box and inshore waters). South of 56°30’ N where the sole fishery operates, the minimum mesh size for towed gears is 80 mm and 100 mm for gill nets. The maximum aggregated beam length for beam trawlers is 24 m. Within the 12-nautical mile zone and in the Plaice Box (see also under plaice) the maximum aggregated length is 9 m, fishing is forbidden for beam trawlers with engine power >300 HP, and a 120 mm mesh applies to otter trawlers fishing for cod. Furthermore fishing is restricted by a days-at-sea regulation which was introduced in the light of the cod recovery plan. [26].

The fishing effort of the major fleets exploiting North Sea sole has decreased since the mid-1990s. At the same time, however, the technical efficiency has increased, which could have counteracted the overall decrease in effort [26].

	Sole	*Solea solea* Family Soleidae	

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